

Analysis of the Variables Affecting Outcome in Fractures of the Distal Radius Treated by Open Reduction and Volar Locking Plate

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ABSTRACT

BACKGROUND: Some variables that could be related to results in fractures of the distal radius treated by open reduction and internal fixation (ORIF) with volar locking plates are still controversial.

PURPOSE: The purpose of this study was to find a possible correlation between various parameters, either patient-related (age, bone quality) or fracture-related (type, reduction), and to analyze the impact of these factors on the radiological and clinical outcome of distal radius fractures treated by volar locking plate.

METHODS: We included a total of 142 patients (145 fractures).

Mean age 56 years (range, 19–87). The primary outcome measures were the following: Radiological (radial inclination, ulnar variance and palmar tilt at 3 and 6 months), clinical (the total Mayo wrist score) and the single score of each domain (pain, function, mobility and grip strength).

RESULTS: At follow-up, in 79 examined wrists (54.4%) there was no pain, in 55 wrists (37.9%) the pain was mild and in 11 (7.5%) cases the pain was moderate. Wrist function was good, and 83 (58.4%) patients returned to their normal activities; in 55 (38.7%) patients, function was slightly impaired, and function in 1 patient was mildly impaired. Unsatisfactory reduction occurred in 21 (14.4%) wrists, including one case of bilateral fracture.

CONCLUSIONS: We found no correlation between the patient's sex or the time between the fracture and surgery and each of the parameters considered. A correlation was found between the type of fracture and three other parameters: the ulnar variance at 3 months, the range of motion and the total score (measured by the Mayo Wrist score). There was a statistically significant difference between type C2 and C3 concerning the ulnar variance at the 3-month follow-up. There was also a difference between type C1 and C3 concerning the range of motion and the total score, with a better outcome in the patients with a type C1 fracture.

Level of evidence: IV (case series).

Key words: Distal radius; Fractures; Osteosynthesis; Volar Locking Plate; Complications; Outcomes

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INTRODUCTION

Distal radius fractures represent almost 17% of skeletal fractures in

adults, with an incidence of 1: 10,000 people^[1]. They occur more commonly in women than men, with a prevalence of 0.37% versus 0.09%, respectively^[2]. It appears that at the age of 60, the residual lifetime risk of wrist/forearm fracture is 15% for women and 1.7% for men^[3].

This type of fracture was first described in 1814 by Abraham Colles, but the management and the choice of treatment is still controversial among orthopedic surgeons. Many treatment methods are available; all share the goal of obtaining and maintaining the fracture reduction with either casting, functional bracing, external fixation, percutaneous pinning, internal fixation or a combination of these options^[4]. The choice depends on many factors that should all be considered when treating these fractures. The initial treatment typically consists of closed reduction and casting; however, fracture re-displacement occurs in approximately 64% of cases^[5,6].

In 1989, Lafontaine *et al* identified and described five factors that predict fracture instability in fractures treated with closed reduction and casting: dorsal angulation exceeding 20° at presentation, dorsal comminution, extension of the fracture into the radiocarpal joint, an associated ulnar fracture and age older than 60 years^[7].

In 2006, Mackenney *et al* investigated predictors of early and late instability, malunion and malalignment^[6]. They concluded that the most important predictive factors were the age of the patient, the type of comminution and the position of the fracture at presentation. Early and late instability and carpal malalignment increase with age; the presence of dorsal comminution was also an important predictive factor of malunion.

More recently, Walenkamp *et al* conducted a systematic review with the aim of identifying predictors of secondary displacement in fractures initially treated with plaster immobilization with or without closed reduction^[8]. The results of the meta-analysis showed a significantly increased risk of secondary displacement in fractures with dorsal comminution and in women. It also showed the importance of age, demonstrating an increased risk in patients older than 60-65 years due to poor bone quality.

The literature on the treatment of distal radius fractures in the elder population is conflicting. It is given that stable fractures can be treated with closed reduction and casting, achieving satisfactory outcomes, although anatomic restoration of the distal radius is essential for better results, and there is a direct relationship between the anatomical result and functional outcomes^[9,10].

Volar locking plates have been demonstrated by several authors to provide a valid option for the management of distal radius fractures in the elder population^[11-15]. The biomechanics of these plates allow oblique orientation of the distal screws to prevent displacement and collapse opposite the plate, maintain anterior cortical continuity and provide a buttress effect to prevent radius collapse^[16]. However, this treatment is not free of complications. Such complications include tenosynovitis, tendon ruptures and plate volar prominence, which can lead to implant removal^[17].

The purpose of this study was to find a possible correlation between various parameters, either patient-related (age, bone quality) or fracture-related (type, reduction), and to analyze the impact of these factors on the radiological and clinical outcome of distal radius fractures treated by volar locking plate.

MATERIALS AND METHODS

This retrospective single-center study included a total of 142 patients, treated between January 2010 and December 2014. The study group consisted of 45 men (31.7%) and 97 women (68.3%), with a mean

age of 56.68 ± 15.8 (range, 19-87). There were 3 cases of bilateral fractures, with a total of 145 distal radius fractures: 64 (44.1%) of the right wrist and 81 (55.9%) of the left wrist (Figure 1).



Figure 1 Fracture of the distal radius of a 62-year-old woman: (A) anteroposterior view; (B) lateral radiograph.

In 40%, the dominant side was injured. The fractures have been classified using the Arbeitsgemeinschaft für Osteosynthesefragen (AO) classification system. Inclusion criteria were type C distal radius fractures; age >18 years; and 3- and 6-month clinical and radiological follow-up. All type A and B fractures, patients with an incomplete follow-up, patients with neurological impairment of the affected limb and patients who were treated with other than a volar locking plate were excluded. Total fractures consisted of 42 type C1, 49 type C2 and 54 type C3 (Table 1).

The present series had 10 cases of associated lesions: 1 case of bilateral proximal humerus fracture; 1 case of IV and V metacarpal bone fracture; 1 case of contralateral diaphyseal radial fracture; 1 case of patellar fracture; 1 case of homolateral supracondylar humeral fracture; 1 case of acetabular fracture; 1 case of homolateral elbow dislocation; 1 case of multiple vertebral fractures; 1 case of tibial plateau fracture, proximal fibular fracture and multiple rib fractures; and 1 case of homolateral metaphyseal ulnar fracture. Three patients showed a Gustilo 1 exposure wound that was treated at the emergency room before the reduction.

Operative Treatment

All the patients underwent an initial closed reduction and casting. Some 24.1% of relapses occurred in the cast, and these patients were then treated surgically. The mean time between the fracture and the surgery was 11 ± 7.8 days.

Surgery was performed under brachial plexus block in all the patients, and an upper limb ischemic tourniquet was always used.

In 141 wrists, a modified Henry approach was used, using the plane between the flexor carpi radialis tendon (FCRT) and the radial artery. After the release of the pronator quadratus muscle, the fracture site was exposed. Fracture reduction was then achieved with the assistance of an image intensifier and was temporarily stabilized with the use of Kirschner wires.

The plate (2.4 mm Variable Angle Volar Locking Compression Plate, DePuy Synthes®; DVR Anatomic Volar Plating System, Biomet®; VariAx Distal Radius Locking Plate System, Stryker®) was placed on the anterior aspect of the radius and then fixed with cortex and locking screws, under image intensifier control (Figure 2).

When possible, the pronator quadratus muscle was reinserted to protect the flexor tendons. After surgery, the wrist was immobilized in a plaster, and active digital motion was immediately started. Two

weeks after surgery, the suture and the plaster were removed and the patient was encouraged to start active and passive wrist mobilization.

In 1 patient with a type C3 fracture in presence of bone loss, artificial bone (Hydroset) was used to achieve a more satisfactory reduction. In 2 patients, a double approach (volar and dorsal) was performed and a dorsal plate was used for support. They were included in this study because dorsal plating was a complementary treatment of volar plating with the aim of getting sufficient stability of the fracture. In 2 patients, a volar approach for the synthesis of



Figure 2 Radiographs of the same patient in Figure. 1, 3 months after surgery: (A) anteroposterior radiograph; (B) lateral view.

Table 1 Demographic and radiologic characteristics.

Age	56.68 ± 15.8	
Sex		
Female	97	68.30%
Male	45	31.70%
Injured Side		
Right	64	44.10%
Left	81	55.90%
AO type of fracture		
C1	42	29%
C2	49	33.80%
C3	54	37.20%
Predictive factors of instability		
Dorsal angulation >20°	67	46.20%
Dorsal comminution	61	42.10%
Associated ulnar fracture	90	62.10%
Relapse in cast after closed reduction	35	24.10%

the radius and a second cubital approach for the synthesis of the ulna were performed, with a bridging plate in one case and with a tension band in the other case.

Radiographic Assessment

Anterior-posterior and lateral view X-rays were taken at the time of the initial injury and after the closed reduction and casting. Postoperative control X-rays were taken the day after the surgery and at 3 and 6 months' follow-up.

The fractures were classified according to AO classification for subtypes C1, C2 and C3. All the X-rays were reviewed by an expert surgeon and a resident. The assessor of the radiographic outcome (R.S.) was not involved in the surgery.

The preoperative X-rays were evaluated for the presence of predictive signs of instability: dorsal inclination $> 20^\circ$, dorsal comminution, extension of the fracture to the radiocarpal joint and presence of ulnar fracture^[7]. In the postoperative views at 3 and 6 months, radial inclination, ulnar variance and palmar tilt were measured in accordance with the methods described by Mann *et al*^[18].

The assessor measured radial inclination in an anterior-posterior view by determining the angle formed between the long axis of the radius and a line drawn from the distal tip of the radial styloid to the ulnar corner of the lunate fossa. The ulnar variance was also measured in an anterior-posterior view by measuring the difference between two parallel lines drawn perpendicular to the long axis of the radius and the distal articular surface of the ulnar corner of the sigmoid notch or the radius. Palmar tilt was measured in a lateral view by determining the angle between two lines: one drawn perpendicular to the long axis of the radius and one drawn between the dorsal and palmar lips of the distal radial articular surface.

According to Medoff, normal values of radiological assessment take into account the patient's sex and should measure as the following: radial inclination $24.7^\circ \pm 2.5$ for women and $22.5^\circ \pm 2.1$ for men; ulnar variance $-0.6 \text{ mm} \pm 0.8$ for women and $-0.6 \text{ mm} \pm 1.0$ for men; palmar tilt $12.2^\circ \pm 5.6$ for women and $10.2^\circ \pm 3.2$ for men^[19]. However, in our series we assessed the normal values following the AO as radial inclination 23° , ulnar variance neutral and palmar tilt 11° - 12° ^[20]. Fracture union was defined as presence of bone bridging of the radial, ulnar and dorsal aspects of the distal radial cortex.

Functional Assessment

At each visit, a clinical examination was performed. The functional assessment included measurement of active wrist extension, flexion, pronation and supination.

In this series, we used the Modified Mayo Wrist Score, which is a physician-based scoring system^[21]. This system provides 4 domains each with a score of 0 to 25 points, for a total of 100 points. The domains examine active flexion/extension as a percentage of the opposite side; ability to return to regular employment or activities; grip strength as a percentage of the opposite side; and pain that is rated by the evaluator, based on the patient's subjective description.

A total score of 90-100 points is considered excellent, a score of 80-89 points is good, a score of 65-79 points is fair and a score lower than 65 points is poor.

Statistical Methods

Metric-scaled data are reported as the arithmetic mean and the standard deviation or range. Categorical data are reported as the absolute frequency and the percentage distribution. A *t*-test for independent samples or a nonparametric Mann-Whitney U test for

the determination of differences of mean values between various groups of patients was also performed. The relation between quantitative data was studied by Pearson's correlation coefficient. An analysis of variance was performed for the comparison between three or more groups. The changes in the radiographic assessment at 3 and 6 months' follow-up were studied by a paired Student's *t*-test or the Wilcoxon test.

RESULTS

Clinical Results

The clinical results are summarized in Table 2. The analysis of



Figure 3 Radiological study of the same patient in Figures 1 and 2, 6 months after surgery: (A) anteroposterior view; (B) lateral radiograph.

Table 2 Clinical outcomes.

Mayo total score	85.07 ± 11.9
Pain intensity	22.34 ± 3.1
Functional status	22.90 ± 2.5
Range of motion	18.10 ± 4.2
Grip strength	21.68 ± 5.0

Table 3 Radiographic outcomes.

	3 Months FU	6 Months FU	Change	P Value
Radial inclination (deg)	22.57 ± 4.0	22.70 ± 4.5	-0.131	0.421
Ulnar variance (mm)	0.83 ± 2.3	0.93 ± 2.3	-0.104	0.14
Palmar tilt (deg)	5.35 ± 5.9	5.13 ± 6.1	0.221	0.084

functional results was performed between May 2th 2018 and May 10th 2018.

At the follow-up, in 79 examined wrists (54.4%) there was no pain, in 55 wrists (37.9%) the pain was mild and in 11 (7.5%) cases the pain was moderate. In 83 (58.4%) patients, wrist function was good and they returned to their normal activities; wrist function was slightly impaired in 55 (38.7%) patients, and in one patient, wrist function was mildly impaired. Concerning the patients with bilateral fracture, in one case, wrist function was completely restored in the right hand and the patient had some limitation in the left hand (with a score of 25 and 20, respectively); one patient reported a slight impairment in both hands; and one patient had a complete restoration of wrist function in the right hand and a slight impairment in the left hand.

The range of motion regarding flexion/extension was more than 120° in 12 wrists (8.2%), was 100°-119° in 87 wrists (61.2%), was 90°-99° in 27 wrists (18.6%), was 60°-89° in 17 wrists (11.7%) and was 30°-59° in 2 (1.3%) wrists.

Grip strength was 100% of the contralateral in 98 (67.5%) patients, including two who reported bilateral fracture; was 75%-100% in 41 (28.2%); and was 50%-75% in 6 (4.1%) cases, including one patient with bilateral fracture who had a loss of grip strength in the right hand and a total restoration of the strength in the left hand.

One patient with a bilateral fracture at the 3-month follow-up showed a mild dorsal deformity in the right wrist due to a collapse of the radius and a loss of reduction.

Radiographic Results

The radiographic results are summarized in Table 3.

Satisfactory reduction (defined as < 10° dorsal tilt, < 2 mm radial shortening and < 1 mm articular incongruity) was achieved in 124 (85.5%) wrists at the 6-month follow-up (Figure 3).

The mean radial inclination at 3 months was 22.57° (± 4), and at 6 months 22.70° (± 4.5). The mean ulnar variance at 3 months was 0.83 mm (± 2.3), and at 6 months 0.93 mm (± 2.3). The mean palmar tilt at 3 months was 5.35° (± 5.9), and at 6 months 5.13° (± 6.1).

Unsatisfactory reduction (defined as > 10° dorsal tilt, > 2 mm radial shortening and > 1 mm articular incongruity) occurred in 21 (14.4%) wrists, including one case of bilateral fracture.

Dorsal tilt was not reduced satisfactorily in 8 fractures (including 3 type C1 fractures, 3 type C2 fractures and 2 type C3 fractures). Radial shortening was not corrected in 4 fractures (including 1 type C1 fracture, 1 type C2 fracture and 2 type C3 fractures occurring in the same patient). Restoration of the articular congruency was not obtained in 13 fractures (including 1 type C1 fracture, 4 type C2 fractures and 6 type C3 fractures).

Radiographic union of the fracture at 3 months was observed in 97.8% of the patients. There were two cases of delayed union of the fracture that showed presence of callus at 6-month follow-up. The fractures were both classified as C3, and in one case with bone loss, a bone substitute (Hydroset, Stryker®) was used to fill the gap and restore the articular surface.

There was no hardware failure, loosening of screws or tendon rupture.

In 5 cases, there was a “gap of reduction” of 2 mm. All the patients were younger than 65 years; 4 of the fractures were classified as type C3, and 1 as type C1.

In one case, a dehiscence of the surgical wound occurred the same day of the surgery. The following day, the patient underwent surgical debridement of the wound and a carpal tunnel decompression was performed.

We attempted to find a correlation between various parameters through a statistical analysis. The parameters considered were both radiological and clinical. They included the measurements of radial inclination, ulnar variance, palmar tilt at 3 and 6 months, the total Mayo wrist score and the single score of each domain (pain, function, mobility and grip strength). These parameters have been correlated with age, sex, time between the fracture and the surgery and type of fracture.

The analysis showed that there is no correlation between the patient's sex or the time between the fracture and surgery and each of the parameters considered. Concerning age, a correlation was found with the ulnar variance at 3 and 6 months ($p < 0.001$).

There was also a correlation between the type of fracture and three other parameters: the ulnar variance at 3 months, the range of motion and the total score (measured using the Mayo Wrist score).

There was a statistically significant difference between type C2 and C3 ($p = 0.048$) concerning the ulnar variance at 3 months' follow-up. Furthermore, there was a difference between type C1 and C3 concerning the range of motion ($p = 0.037$) and the total score ($p = 0.034$), showing a better outcome in the patients with a type C1 fracture.

We also divided the patients into two groups depending on their age, comparing these data with the radiographic and clinical results. Eighty-nine (62.6%) patients were younger than 65 years and 56 (39.4%) patients were older than 65 years. Of all the parameters examined, a statistically significant correlation was found only for the ulnar variance at 3 months' follow-up ($p = 0.007$) and the ulnar variance at 6 months' follow-up ($p = 0.013$).

DISCUSSION

The purpose of this study was to find patient and fracture-related factors, which can predict the clinical and radiological outcome of distal radius fractures treated with a volar locking plate. We were primarily interested in demonstrating the correlation between these factors with statistically significant data.

We believe we have found a correlation between the ulnar variance at 3 and 6 months, age and type of fracture. The increase in the ulnar variance at the follow-up demonstrates the collapse of the radius, showing either loss of reduction, poor bone quality, or both.

In fact, bone quality is strongly related to the accuracy of the reduction and the stability of the synthesis. Elderly patients and complex comminute fractures (C2, C3) have the poorest prognosis in terms of clinical and radiological outcome.

Many authors have suggested a high correlation between the anatomical result and the functional outcome in young, active

patients. Restoration of articular congruity and radial length with open reduction and internal fixation (ORIF) is strongly recommended in younger patients^[22]. However, in the literature, few authors highlight the importance of anatomical restoration of the articular surface and radial length in order to achieve acceptable outcomes in elderly patients. The literature is very heterogeneous on this matter, given many different treatments are described for these fractures.

Jupiter *et al* selected 20 patients older than 60 years, who underwent ORIF with a Volar Locking Plate for the treatment of redisplaced Colles-type distal radial fractures^[23]. They evaluated these patients after an average 38-month follow-up, using the Patient-Rated Wrist Evaluation and the Physical Activity Scale for the Elderly. They obtained 7 excellent results, 11 good results and 2 fair results. The authors conclude suggesting ORIF as a treatment for displaced distal radial fractures in older patients with previous failure of nonoperative treatment.

Sharma *et al* analyzed outcomes and complications of type B and C distal radius fractures, comparing patients who underwent nonoperative treatment and patients treated with a volar locking plate^[16].

Concerning clinical results, at the 6-week follow-up, the plating group had a significantly ($p < 0.001$) better range of movement and grip strength than the nonoperative group. At the final follow-up, the plating group still showed better range of movement concerning dorsal flexion, palmar flexion, supination, pronation and grip strength ($p < 0.001$). Regarding radiological results, at the last follow-up, the plating group had significantly ($p < 0.001$) better values in terms of radial inclination, volar tilt and radial length. There were no differences in ulnar variance. Articular step-off (≥ 2 mm) was present in 16 patients of the nonoperative group and 4 patients of the plating group, at 6 weeks postreduction/postoperative.

In terms of the plates, new implant designs include low-profile plates, volar fixed-angle implants and other features that have made plating a popular option. Furthermore, this study showed that radial height and volar tilt were better restored by internal fixation, suggesting that internal fixation could provide a more accurate articular reduction and lower the rate of osteoarthritis.

Egol *et al* conducted a comparative study between surgical and conservative treatment for distal radius fractures^[24]. All displaced fractures were initially approached with closed reduction and splint. Surgery was indicated in open fractures, fractures with unstable patterns, fracture dislocation of the wrist and fractures that lost reduction and met radiographic criteria for surgery. Surgical treatment consisted of a volar locking plate or bridging external fixation with supplemental K-wire. Clinical and radiographic outcomes were better in the operative group at each follow-up. The authors also found a higher incidence of grade-1 arthritic change in the nonoperative group at 1-year follow-up.

In 2007 Rampoldi and Marisco studied 90 patients treated by volar plate fixation, focusing on the complications found^[25]. The overall rate of complications was 8% (7 cases). Tendon rupture or irritation of extensor (3 cases) and flexor tendons (2 cases) were the complications most commonly encountered. All but one were clearly related to direct attritional damage of the tendon caused by the prominent edge of the plate or by protruding screw tips. Loss of reduction needing repeat internal fixation was seen in one marginal shear fracture involving the lunate facet fragment. One patient had a carpal tunnel release due to median nerve irritation. Volar plate fixation appeared as a safe surgical technique in the management of unstable distal radius fractures, with a low incidence of complications. Accurate placement of the plate and exact measurement of the screws

may further minimize the rate of complications. When radiographs reveal circumstances that may predispose to tendon attritional lesions (prominent edge of the plate, dorsal protrusion of the screw tips) early removal of the fixation device was strongly recommended^[25].

In 2017 Thorninger *et al* analyzed 576 patients with a median age of 63 years (range: 15-87)^[26]. Seventy-eight percent were female and the mean observation time was 3.2 years (range: 2-5.4). Seventy-eight percent of the patients were treated with VariAx[®] and 22% with Acu-Loc[®]. The overall complication rate was 14.6% including carpal tunnel syndrome or change in sensibility in 5.2% and tendon complications in 4.7%. Five flexor tendon ruptures and 12 extensor tendon ruptures were encountered. The reoperation rate was 10.4% including 41 cases of hardware removal. A statistically significant association between AO/OTA fracture type C and complications was observed. No statistically significant association between complication rate and surgeon experience and type of plate was detected^[26].

This study has certain limitations: its retrospective nature; the relatively small sample size in distal radius fractures that included young as well as elderly patients; we did not sufficiently investigate the outcome predictors especially ulnar variance; it is not a comparative study and has a short-term follow-up, although we believe we have demonstrated that volar locking plates can be a good option for the treatment of distal radial fractures in both young and elderly patients. On the other hand, the strengths of our study were that we included only type C radius distal fractures for study of outcome predictors; and that the assessor of radiological outcome was not included in the surgical team to minimize bias.

In conclusion, our study found no correlation between the patient's sex or the time between the fracture and surgery and each of the parameters considered. In terms of age, a correlation was found with the ulnar variance at 3 and 6 months. There was also a correlation between the type of fracture and three other parameters: the ulnar variance at 3 months, the range of motion and the total score (measured using the Mayo Wrist score). There was a statistically significant difference between type C2 and C3 concerning the ulnar variance at 3 months' follow-up. Furthermore, there was a difference between type C1 and C3 concerning the range of motion and the total score, showing a better outcome in the patients with a type C1 fracture.

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